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REVOLUTION IN THE TOPOGRAPHY OF THE PACIFIC COAST SINCE THE AURIFEROUS GRAVEL PERIOD.[1]

INTRODUCTION.

It is now generally recognized that rivers are the architects and sculptors of their own valleys. The land is everywhere shaped largely by its streams, and the forms developed are serial, beginning with the river's youth and changing in the progress of time until finally the stream attains old age, and its topographic work is completed. In their early life, when rivers have their highest grade, they wash away their beds more than their banks, and cut cañons. Their beds are a succession of gentle flows, rapids, and falls, over the softer and harder beds. When by deep cutting the fall of the stream is reduced, it tends to spread out and erode its banks, the cañons widen, and the divides become narrow and sharp, with rugged peaks showing the stream's maturity, but the work of the fluvial sculptor still continues, and the mountains are reduced to hills and the hills to knolls so low that the general aspect of the country is that of a plain. The streams are powerless to erode the land below the level of this gentle plain, which has been appropriately named by Powell the Baselevel of Erosion. Thus in a complete cycle of a river's history the cañon and the broad divide, or plateau, are features of its youth; narrow, sharp, more or less rugged divides of its maturity, and the baselevel of its old age. The cañons have then disappeared, and the land reduced by long continued erosion approximately to sea level.

The development of the baselevel begins upon the seashore by which the level is determined, and gradually spreads inland toward the principal divides. Under similar conditions the shales and limestones wear away more rapidly than the coarser sediments and crystalline rocks, and local baselevels appear for a time determined by the harder rocks. But these are all obliterated in a general baselevel when it is completely developed. The land is so unsteady that it rarely, if ever, remains without elevation or depression long enough for the complete development of a baselevel of erosion. It commonly happens, however, that the large masses of harder rocks upon the slopes of the principal divides form independent elevations in the plain which may be more or less distinctly defined upon the softer rocks. The topography of the region is then essentially a peneplain.

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[1] Published with the permission of the Director of the United States Geological Survey. Abstract from a paper upon the same subject which will appear in the 14th Annual Report of the United States Geological Survey. Read before the Geological Society of Washington, April, 1893.

It is evident that a general baselevel of erosion must have originated approximately at sea level. This is the only position in which a very extensive baselevel of erosion can originate. If we now find such a baselevel at considerable elevation above the sea, its position furnishes evidence that since the baselevel was formed the country has been uplifted in the process of mountain building.

Upon our Atlantic slope, ancient baselevels of erosion are well developed in the Piedmont region and elsewhere at considerable altitudes above the sea, as shown by Davis, McGee, Willis, Hayes, and Campbell. The ancient mountains have been swept away, and the modern mountains, at least in large part, are the result of later upheavals. Similar changes have taken place on the Pacific slope. Russell found in the St. Elias range, at an elevation of over 5,000 feet, shells of marine mollusks still living along the Pacific coast, showing that the great mountain range had been uplifted in very late geologic time. So, also, the Sierra Nevada and Coast ranges, and to some extent the Cascade range, now such prominent features of the Pacific coast, have been upheaved to their present great height, and deep cañons cut upon their slopes in the later geologic ages. At an earlier epoch the whole country was comparatively low and near sea level, or, in other words, near its baselevel of erosion. The mountain ranges were then inconspicuous and the slopes everywhere gentle.

It is the object of this paper to trace out this ancient topography and briefly to outline the great changes by which the present features were developed. Incidentally the auriferous gravels will be considered, because they originated in large part at the beginning of its topographic revolution, which has on this account a most important economic interest.

TOPOGRAPHY OF THE PACIFIC SLOPE.

There are two prominent topographic belts on the Pacific slope. One is the platform of the interior basin region, and the other the mountain belt which lies upon the border of the continent. The latter embraces the Sierra Nevada, Cascade, and Coast ranges, as well as the Klamath Mountains in northwestern California and southwestern Oregon, where all the ranges meet. Between the ranges to the southward of the Klamath Mountains lies the Great valley of California, and to the northward the Sound valley extends from central Oregon across the state of Washington. The mountains are everywhere deeply cañoned by the rivers, but if we take a more general view, overlooking those features which are still developing, we shall discover others of much greater antiquity.

ANCIENT BASELEVEL OF EROSION.

Upon the northwestern and northern border of the Sacramento valley.—Upon the northwestern border of the Sacramento valley is a well-marked plain of erosion, which extends for nearly one hundred miles from about the 40th parallel around the northern end of the Sacramento valley to near the Great Bend of Pit river. It varies from one to fourteen miles in width, and is best marked in the Greasewood and Bald hills of Tehama and Shasta counties. The larger portion of the plain has been carved upon the upturned edges of the Cretaceous strata, and the denudation has reduced the thick, hard conglomerates and sandstones to the same level as the soft shales. At a number of places the well-defined plain extends for several miles into the area of harder and more durable metamorphic rocks of the Klamath Mountains. Excellent views of this plain may be obtained from the Red Bluff and Hayfork stage road, five miles northwest of Hunter's postoffice, and from the mountain roads and trails leading westward from Stephenson's, Miller's, Lowrey's, and Paskenta, in Tehama county.

In the Klamath Mountains.—The plain already noted lies at the southeastern base of the Klamath Mountains, and passes by gradual and rapid transition into the steeper slopes of the mountains in such a way as to indicate that the plain may have once extended across the region now occupied by the Klamath Mountains. Within that group the plain has been recognized thirty miles southeast of Humboldt bay, about Shower's pass, at an altitude of nearly 4,000 feet, and a little farther east, in the even crest of South Fork Mountain, at an altitude of 6,000 feet. Major J. W. Powell informs me that he has observed a deformed baselevel in the Coast Range north of San Francisco. It will doubtless yet be found at many points, but on account of the great deformation which has taken place in the Klamath Mountains and Coast Range since the baselevel was formed, it is difficult to trace.

On the western slope of the Sierra Nevada.—The baselevel we have followed from Elder creek to Pit river was evidently determined by a body of water occupying the Sacramento valley, and traces of a corresponding level might be expected along the opposite shore about the Sierra Nevada.

The western slope of that range may be briefly described as an inclined plane, interrupted only by the narrow cañons of the present streams. Professor J. D. Whitney graphically portrayed the region as follows: "To one standing on some point, not too elevated, but from which a good view of the surface of the country along the flanks of the Sierra may be had, its slope will appear to be quite uniform and unbroken to one looking along a line parallel with the general trend of the range. It will seem, provided the point of view be favorably selected, as if the whole region was a gently descending plain, sloping down to the Great valley at an angle of not more than two or three degrees. And the slope of the Sierra is—in the mining region at least—quite moderate, for if we allow a rise of 7,000 feet from the lower edge of the foothills to the crest of the range, the distance between the two points being about seventy miles, the average rise is only 100 feet to the mile, which gives an angle of slope of less than two degrees. And if one ascends the Sierra, keeping on the divide between any two rivers in the mining districts, he will find himself, for most of the time at least, on what seems to be a plain with a very gentle rise. Let the traveler, however, turn and attempt to make his way across the country, in a line parallel with the crest of the range, and he will discover that this apparent plain is cut into by the gorges or cañons in which the present rivers run, in a most extraordinary manner; he will find it several hours' work to descend into one of these and rise again to the general level on the other side, even if assisted by a well-beaten trail. All along the western slope of the Sierra the streams have worn for themselves deep cañons, and it is these tremendous gorges which form the leading feature of the topography of the region. If the streams ran nearly on a level with the general elevation of the surface, the whole character of the mountain slope would be changed. This was formerly the condition of the drainage of the Sierra slope."[1] Concerning the topography of the same region, Mr. Ross E. Browne remarks that "at certain favorably located points an extended view is obtained of the Forest Hill and neighboring divides. Upon losing the effect of the detail, one receives the impression of a general uniformity in the grades of the summit-lines. These summit-lines appear as the remaining traces of a gently undulating plain, sloping regularly from the bases of the massive peaks of the Sierra to the Sacramento valley."[2] Extended views of the western slope of the Sierra Nevada may be obtained at many points from the Central Pacific railroad between Colfax and the summit, and they fully illustrate the feature referred to.

[1] Auriferous Gravels of the Sierra Nevada of California, by J. D. WHITNEY. Pp. 63-64.

[2] The Ancient River Beds of the Forest Hill Divide. Tenth Annual Report of the State Mineralogist of California, 1890, p. 435.

This uniformity of gentle slope is enhanced in some cases, especially in the region of the American and Yuba rivers, by the broad, flat-topped lava flows which occupy the divides between the cañons. Sometimes it appears that the volcanics are thin, while at other places, according to Whitney their thickness is very large, quite often reaching 400 or 500 feet, and occasionally much exceeding that amount. The plain, however, is not limited to the areas occupied by volcanic rocks, but has a wide distribution over areas of closely folded auriferous slates, and cannot be attributed to the constructive effects 'of volcanic eruptions.

Mr. Gilbert was the first to call attention to the fact that this uniform surface is due to erosion upon a system of plicated strata, and "could only have been accomplished by streams flowing at a low angle,"[1] in other words, the plain must have originated essentially as a baselevel of erosion.

Judging from the topographic maps recently prepared for the geological work in the gold belt, as well as from the observations of Whitney,[2] Petty,[2] Goodyear,[2] Lindgren,[3] Turner, and myself, it appears that the inclined plateau which now forms the western slope of the Sierra Nevada was originally not worn down to so complete a plain as that already described upon the western side of the valley.

Mr. Lindgren (l. c.) says, "that the Sierra Nevada, before the accumulation of the gravels began, was a mountain range greatly worn down by erosion, but not reduced to a baselevel of erosion. It cannot even, on the whole, be regarded as a peneplain, above which isolated and more resistant hills projected. The declivities and irregularities of the old surface are too considerable for that, nor are the projecting hills invariably composed of the hardest rock-masses."

While some of the irregularities now recognized in the old plain upon the western slope of the range are due, as urged by

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[1] Science, Vol. 1, p. 195, March 23, 1883.

[2] Auriferous Gravels of the Sierra Nevada of California.

[3] Two Neocene Rivers of California. Bull. Geol. Soc. of America, Vol. 4, p. 298.

Mr. Turner, to protruding hard rocks, it is possible that a considerable portion resulted from deformation when the Sierra Nevada was upheaved. For it will be shown later on that since this peneplain was formed by erosion, the Sierra Nevada has been greatly uplifted, and it would be very remarkable indeed if in the upheaval of such an enormous mass as the Sierra Nevada the original plain of its western slope were not warped and broken.

Platform of the interior region.—The fact that the baselevel plain passes to the eastward from the northern end of the Sacramento valley beneath the lavas of the Lassen Peak district, suggests that it may reach the platform of the interior region, which is now covered by volcanic material. Within northeastern California and the adjacent portion of Oregon there are vast stretches of level plains which are nearly of the same altitude above the sea. As far as known, all the surrounding hills and mountains are of lava. There are no projecting peaks of older rocks, and their absence from wide stretches of plateau country tends to show a general level of the subjacent surface analogous to that of the interior plateau in British Columbia described by Dr. G. M. Dawson.

The erosion plains we have traced upon the borders of the Sacramento valley, in the Klamath Mountains, upon the western slope of the Sierra Nevada, and probably also in the interior region of northeastern California, join one another in such a way as to show that they are simply different portions of one extensive baselevel of erosion which formerly spread over a large part, if not the whole, of middle and northern California and the adjacent portion of Oregon. What is the geological age of this plain of erosion?

DEPOSITS UPON THE BORDER OF THE ANCIENT BASELEVEL.

General statement.—In order to determine the conditions under which the baselevel was developed, and its age, it is necessary to study the formations deposited during its development. At the eastern edge of the baselevel, in the Sacramento valley, there are three formations, all of which were more or less influenced by it in their distribution. Only two of these, the middle and the lower, need here be considered. The middle formation is a tuff which has already been called the Tuscan tuff. Below the Tuscan tuff and above the Cretaceous are gravels, sands, and clays, which apparently occupy the exact taxonomic position of the Ione formation of Becker, Lindgren,[1] and Turner, and may therefore be appropriately designated by the same name.

Tuscan tuff.—The Tuscan tuff is composed wholly of volcanic material. It will be considered first, for the reason that it can be most easily identified in different localities, and can be used to great advantage as a reference plane in considering the Ione.

On the western border of the Sacramento valley the most southern exposure yet observed is on Thomes creek, four miles east of Paskenta. From this point it has been traced with varying thickness for fifty miles across all the streams, cutting the eastern margin of the baselevel from Elder creek to Redding. It continues, with interruptions, around the northern end of the Sacramento valley to the thick deposits of similar material in the Lassen Peak region. It thins out to the westward and laps over on the baselevel in such a way as to indicate that the baselevel was formed before the great volcanic eruption which gave birth to the tuff.

Ione formation.—Beneath the Tuscan formation lies the Ione, which rests upon the upturned and eroded edges of the Cretaceous (Shasta-Chico) strata with conspicuous unconformity. In the Bald Hills region, northeast of Paskenta, it is composed of clay, and thins out rapidly to the westward against the edge of the baselevel. Farther northward the formation thickens somewhat, and contains much gravel, but everywhere it thins out rapidly to the edge of the baselevel. In the Lassen Peak region, beneath the lava, it has its greatest development, and is many hundreds of feet in thickness. To the northeastward it borders

[1] Geological Atlas of the United States. Text accompanying the Sacramento sheet.

upon the baselevel of the Klamath Mountains, while in the opposite direction it appears to stretch up to the high plateau at the northern end of the Sierra Nevada, and shows the features already noted of tapering abruptly to the edge of the baselevel plain. This formation might be considered a fringe to the baselevel, and evidently was deposited at least in part during the baselevel period.

The earlier auriferous gravels upon the slopes of the Sierra Nevada are older than the volcanic flows of the same region. They are regarded by Messrs. Turner and Lindgren and the writer as of essentially the same age as the Ione formation in the Great valley of California. The auriferous gravels were accumulated and deposited upon the flanks of the range, while the finer material, sand and clay, were carried into the Sacramento valley.

AGE OF THE BASELEVEL OF EROSION.

The age of the baselevel must be determined by reference to the formation with which it is associated. It is evidently of more recent origin than the Cretaceous, since it truncates the upturned edges of the Shasta-Chico series, and these are the youngest strata upon which it has yet been seen. It was already developed at the time the earlier auriferous gravels were deposited, for they lie in the broad shallow valleys which belong to the baselevel plain. The erosion by which it was developed therefore occupied a part or the whole of the time interval between the upheaval of the land at the close of the Chico epoch (Cretaceous) and the deposition of the auriferous gravels.

The age of the earlier auriferous gravels has not yet been fully determined, although they have been the subject of much investigation. That of the later gravels will not be considered here. Professor J. D. Whitney, in his "Auriferous Gravels of the Sierra Nevada of California," page 283, says: "It appears probable, on stratigraphical grounds, that the detrital beds overlying the bed rock of the Sierra Nevada represent the whole

Tertiary period, that is, that they have been forming since the beginning of that epoch.[1] . . . The evidence of the geological age of the gravel deposits afforded by the plants found in the sedimentary beds underlying the latest eruptive masses in the mining region of the Sierra has already been discussed by Mr. Lesquereux. He distinctly recognizes the presence in this flora of forms identical with or closely allied to those of the Miocene; but still calls the age of the group Pliocene. Something of the same kind seems to be legitimately inferred from the animal forms of the same deposits. There are certain fossils which have been found only in deep-lying gravels like those of Douglas Flat and Chili Gulch. No traces of the rhinoceros, the elotherium or the small equine animal referred with doubt by Leidy to Merychippus have ever been found in deposits which could by any possibility be proved to be more recent than the basaltic overflow. It is true that the evidence thus far collected is but fragmentary. Still, taking it for what it is worth, it may be said that the affinities of these animals found in these lower deposits would indicate a Miocene rather than a Pliocene age. There are also, it is believed, stratigraphical reasons for admitting that some at least of the deposits containing these older fossils may be proved by other than palæontological evidence to belong to an older series than those strata which, though anterior to the basalts, yet contain a fauna decidedly mere Pliocene than Miocene in character."

A collection of plants made from the older auriferous gravels upon the northern end of the Sierra Nevada was examined by Professor Lesquereux, who reported that their relation is evidently to the Miocene (U. S. Geological Survey, Eighth Annual Report, p. 419). Professor L. F. Ward, who examined the same collection, agreed that they were Miocene, most likely upper Miocene.

Recently the evidence afforded by the plant remains has been ably reviewed by Professor F. H. Knowlton, who studied extensive collections from the auriferous gravels of Independence Hill, Placer county, California. He concludes that the gravels are probably upper Miocene in age.[1]

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[1] By the Geological Survey of California the Tejon was regarded as Cretaceous. Palæontology, Vol. 2, p. xiii. It is now regarded as Eocene, and in Oregon lies unconformably on the Shasta-Chico series.

On stratigraphic grounds the auriferous gravels are regarded as contemporaneous with the Ione formation of the Sacramento valley, but here, too, as in the earlier auriferous gravels, the fossil plants and shells appear to indicate that they belong to the Miocene.

That the approximate baselevel reached its greatest development about the time the earlier auriferous gravels were deposited is indicated by the fact that they lie in the broad shallow valleys of that plain. The present tendency of the organic evidence contained in the flora of these gravels is to indicate that their deposition took place during the Miocene, most likely later Miocene. The erosion necessary to develop the baselevel out of the topography resulting from the uplift at the close of the Shasta-Chico period must have occupied a long interval of time, possibly beginning in the latter part of the Cretaceous and continuing through the Eocene and earlier portion of the Miocene, but as the plain appears to have attained its maximum extent during the Miocene, it may be referred to as the Miocene baselevel.

THE ELEVATION INDICATED BY THE FLORA OF THE AURIFEROUS GRAVELS.

The flora of the region indicated by the remains found in the earlier gravels is of special interest on account of its bearing on the topography. Numerous fossil leaves have been found in the early auriferous gravels about the northern end of the Sierra Nevada at Mountain Meadows, near the summit of Spanish Peak and elsewhere on the very crest of the Sierra, at altitudes ranging from 2,900 to 6,350 feet above the sea. These plants were studied by Professor Lesquereux, who recognized among them three kinds of figs and a large number of lauraceous plants, with other forms of similar significance. Not a single species of pine or fir, such as constitute the prevailing arboreal vegetation of that region to-day was recognized in the collections.

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[1] U. S. Geological Survey, Bulletin 108, page 104.

In answer to a question concerning the climatic conditions of that region during the Miocene, as indicated by this flora, Professor Lesquereux stated that "by the presence of a large number of Laurineæ the flora becomes related in its general characters to that of a region analogous in atmospheric circumstances to Florida." With this view Professor Lester F. Ward fully agrees, and also Mr. F. H. Knowlton, who has lately given much attention to the flora of the auriferous gravels.

Mr. Knowlton, says "Lesquereux, as already stated, argued that the presence of a large number of lauraceous plants indicated a region analogous in atmospheric circumstances to Florida. From my own studies, which embrace a much larger amount of material than Lesquereux had, I am not only prepared to accept this statement but to show that it was even stronger than he could have made it out."

Florida is a comparatively low country, rising nowhere more than a few hundred feet above the sea, and it is reasonable to infer that during the early gravel period northern California, which was then analogous in atmospheric circumstances to Florida, could not have been a region of high snow-tipped mountains as it is to-day.

It is well known that during the Miocene tropical conditions extended much farther north than now, and under such circumstances it is possible that certain forms of plants may have had considerably greater range in altitude than their relatives in California have to-day.

No doubt the Sierra Nevada existed at that time, but was a very low range, at least in the northern portion, as compared with its present altitude. Yet it was high enough to supply the alder, birch, poplar, and willows, as well as the few pine leaves lately found by Mr. Turner.[1]

The evidence afforded by the flora of the region is in complete harmony with the inference drawn from the topographic relations, namely, that during the Miocene the country was a series of plains and peneplains with low mountain ranges, or in other words, the country was but little above its baselevel of erosion. In no other position could such extensive plains have been formed by erosion.

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[1] Bulletin Philosophical Society of Washington, Vol. 11, p. 391.

GEOGRAPHY OF NORTHERN CALIFORNIA DURING THE MIOCENE.

The Ione formation being well stratified was evidently laid down in a body of water having a distribution at least as extensive as the formation itself. In the Sacramento valley, as far north as Marysville Buttes, the water of the bay was salt, as shown by the marine shells found at that point by Mr. Lindgren.[1]

Upon the borders of this bay, at Ione, where the conditions were favorable for the accumulation of the vegetable matter to form lignite, the water was regarded as fresh or brackish. Farther northward only unios have been found, and the water in which the Ione formation originated was fresh. Beyond the Lassen Peak region in northern California the water was undoubtedly fresh, but whether one large lake or a series of lakes, or a water body connected directly with that of the Sacramento valley as an estuary from the sea, is a matter of doubt.

From the Great valley the sea swept across the region of the Coast Range, perhaps near the latitude of Sacramento, and extended northward over the area of the broad belt of sandstones upon the western slope to beyond Humboldt Bay. The borders of the land must have been low and swampy to make the conditions favorable for the accumulation and preservation of vegetable matter to form coal. The Sierra Nevada and Klamath Mountains themselves were low, with gentle slopes as compared with those of the present ranges, and the streams flowed down their flanks in broad, shallow valleys instead of in deep cañons as they do now.

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[1] Geologic Atlas of the United States, text accompanying the Sacramento sheet. See also U. S. Geological Survey Bulletin,No. 84, by W. H. DALL and G. D. HARRIS, p. 197.

DEFORMATION OF THE BASELEVEL.

It is evident that since the Miocene there have been great changes of level in northern California, for instead of the original baselevel of the erosion, we have now prominent mountain ranges, whose sides are furrowed by the deep cañons of the rejuvenated streams.

The deformation of the baselevel may be studied along two lines of evidence: (1) by tracing the present variations of altitudes in the original baselevel, which must have had a very gently sloping surface itself, and (2) by tracing the deformation of the Ione deposit which, when laid down, must have been below sea level at a lower altitude than the baselevel, because deposited in the water body upon its border. Each line of evidence should corroborate the other and render conclusions concerning the deformation more trustworthy.

It is impossible to tell from what is known at present the original inclination of the baselevel. It is evident, however, that it must have been considerably less than one degree, for at that angle streams generally erode their beds much more than their banks, and cut cañons.

Upon the western edge of the baselevel, at the foot of the Klamath Mountains in Tehama county, the altitude is nearly 2,300 feet, while upon the eastern edge it is considerably less than 1,000 feet, giving the old plain in the Greasewood hills a slope of 100 feet to the mile to the eastward. Across this plain the present streams flow in cañons 300 to 400 feet deep, and they are still cutting. The cañons in general are deepest to the westward and gradually run out to the Sacramento river in the newer deposits which fill the valley. It is evident that since the baselevel was formed, it has been affected by differential elevation in the uplifting of the Coast Range and Klamath Mountains, just north of the fortieth parallel, to the extent of over 2,000 feet, and if we may judge from the traces of the baselevel seen at Shower's pass and South Fork Mountain, the upheaval in the Klamath Mountains has been much greater. It has long been maintained by Whitney and others that the principal upheaval of the Coast Range occurred at the close of the Miocene.

At the northern end of the valley the elevation of the base level is 800 feet. To the eastward it rises gradually to 1,300 and 1,700, and finally in the neighborhood of Round Mountain to 2,500 feet, showing elevation in the Lassen Peak and Sierra Nevada region east of the Sacramento valley.

Mr. G. K. Gilbert[1] was the first to recognize the broad plateau upon the western slope of the Sierra Nevada as a plain of erosion, and discussed the matter in such a way as to show that the height of the range has been considerably increased since the erosion plain was formed.

Professor LeConte advocated essentially the same view. He says :[2] "The rivers, by long work, had finally reached their base levels and rested. The scenery had assumed all the features of an old topography with its gentle flowing curves. At the end of the Tertiary came the great lava streams running down the river channels and displacing the rivers ; the heaving up of the Sierra crust block on its eastern side, forming the great fault-cliff there, and transferring the crest to the extreme eastern margin ; the great increase of the western slope and the consequent rejuvenescence of the vital energy of the rivers ; the consequent down-cutting of these to form the present deep cañons and the resulting wild, almost savage, scenery of these mountains."

The observations of Mr. W. Lingdren[3] in the region of the Yuba and American rivers upon the western slope of the Sierra Nevada, "appear to prove that the grades of the remaining Neocene gravel channels are to a certain extent determined by the directions in which they flowed, in such way as to strongly suggest that the slope of the Sierra Nevada has been considerably increased since the time when the Neocene ante-volcanic rivers flowed over its surface. It finally appears probable, from a study of the grade curves of the remaining channels, that the surface of the Sierra Nevada has been deformed during this uplift, and that the most noticeable deformation has been caused by a subsidence of the portion adjoining the Great valley relatively to the middle part of the range."

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[1] Science, Vol. 1, March 23, 1883, pp. 194–195.

[2] Bull. Geol. Soc. of Am., Vol. 2, pp. 327, 328.

[3] Bulletin of the Geological Society of America, Vol. 4, p. 298.

Strong evidence of the deformation is furnished by the distribution of the Ione formation. As already shown, this formation was deposited about sea level. On Little Cow creek it now occurs at an altitude of 3,400 feet, and on Bear creek about 4,000 feet above the sea, indicating conclusively that since the base-level period the Lassen Peak region has been elevated at least 4,000 feet. There are indications that the elevation was still greater to the southward about the northern end of the Sierra Nevada, for between Mountain Meadows and Diamond Peak opposite Susanville the auriferous gravels supposed to belong to the estuarine Ione formation rise from 5,000 to 7,000 feet. These high gravels upon the northeastern block of the Sierra Nevada have been displaced in a remarkable manner by the upheaval of the range. The area occupied by them is about 10 × 16 miles in extent. Although the gravels cover the larger part of this area and are connected throughout, they do not appear over the whole of it. There were a few small islands of older rocks during at least the later portion of the gravel period, and at some other places within the area the gravels have either been washed away or covered up by later volcanic flows.

During the later part of the gravel period in that region, after the effusion of the andesitic lavas, more or less well defined beaches were formed around a series of volcanic islands upon what is now the very crest of the range from Fredonia Pass northeast of Mountain Meadows to Diamond Mountain. When developed, these beaches must have been at the same level in a body of standing water, but now they gradually rise to the southward from about 5,000 feet near the northern end of Mountain Meadows to 7,000 feet opposite Diamond Peak, and it is evident not only that the northern end of the range has been elevated but that the amount of elevation increased to the southward. The general inclination of this body of gravels toward Lassen

Peak, beneath whose lavas it disappears, makes it very probable indeed that they are connected with the Ione formation that disappears under the opposite edge of the same lavas bordering upon the eastern side of the Sacramento valley. If this could be definitely established it would show that the northern end of the Sierra Nevada has been elevated 7,000 feet since the gravel period of that region. It is possible that the increased elevation does not extend far to the southward, for beyond the 40th parallel the eastern crest of the range retreats to the escarpment of the main block of which the Sierra Nevada is composed.

In connection with the upheaval of the northeastern portion of the range a fault was formed along the eastern base at least beyond Honey Lake. A short distance above Janesville the gravels are displaced by a fault in which the throw is about 3,000 feet. On the very crest of the range, seven miles northwest of Janesville, the gravel rises to 7,400 feet, while at the foot of the steep slope which it caps the same gravel occurs in Mr. Weisenberger's mine at an elevation of about 4,300 feet. To the northwestward the fault runs out apparently in a monoclinal arch, later than the volcanic eruptions on the crest of the range at that point,[1] but before the final eruptions of the Lassen Peak region were completed. Mr. Lingdren has shown[2] that further south the eastern slope of the range was formed before the eruption of the andesitic lavas. There is some evidence of a similar character in the Honey Lake Region.

ORIGIN OF THE EARLIER AURIFEROUS GRAVELS.

The Tejon epoch appears to have been brought to a close, and the Niocene initiated, in northern California, without any marked change of level, unless a general subsidence,[3] so that the influences in operation during the Tejon continued into the Miocene. The old streams still carried on their enfeebled erosion, and in some places the land was completely reduced to

[1] See also Eighth Annual Report U. S. Geological Survey, p. 429.

[2] Bull. Geol. Society of America, Vol. 4, pp. 257–298.

[3] DALL and HARRIS: U. S. Geol. Survey, Bull. 84, p. 278.

baselevel. The removal of material was chiefly by solution, and the insoluble residuary material thus set free by the disintegration of the rocks accumulated to considerable depths upon the land.

The long period during which the land of northern California remained comparatively stationary, and which enabled the streams in many parts of that region to practically complete their cycles of erosion from youth to old age, was brought to a close by the initiation of an orogenic movement which generally increased the grade of the streams upon the western slope of the Sierra Nevada. At first the differential change of level was very moderate and increased the declivity of the streams but little, but being long continued it became in time revolutionary in its effects, and finally, accompanied by extensive volcanic eruptions, gave birth to the High Sierra of to-day with the deep cañons upon its western slope.

The first result of this change of slope was to rejuvenate the streams and invigorate erosion. On account of surface deformation which must have accompanied the upheaval of such a large mass as the Sierra, the stream grades would be differently affected even along the same channel, and in fact, as Mr. Lindgren has pointed out, in at least one case, owing to direction of flow, the stream grade has been not only diminished but reversed.[1]

The country being covered by a thick coating of soft residuary material, of which the great mass was fine particles, erosion was easy. There were coarser fragments of quartz, largely vein matter, as well as boulders of disintegration which had withstood the chemical changes. The streams readily became loaded not only to their full capacity but overloaded with the mass of fine material, and were thus forced to deposit the coarser particles. The grains and fragments not quite suspendable under the conditions of load were rolled along the bottom and rounded by attrition.

In this way the old channels of the baselevel period became filled with gravel of which by far the larger part is quartz. In the same way the gold, being heavy, and associated with the quartz originally, accumulated in the same channels, while the fine light detritus was carried directly to the Sacramento valley.

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[1] Bul. Geol. Soc. of Am., Vol. 4, p. 281.

In his paper on the ancient river beds of the Forest Hill divide,[1] Mr. Ross E. Browne classifies the auriferous gravel channel systems into three periods. The first period was prior to the first important flow of volcanic cement, the second was contemporaneous with the series of volcanic cement flows, and the third following immediately after the last important flow of volcanic cement extends to the present time. He has called attention to the predominance of quartz gravel[2] and sand in the ancient channels of the first period, and remarks that "quartz is the only important material contained in the belts (of slates) which is hard and permanent enough to resist the destructive action of the current." This is especially true when the auriferous slates are disintegrated. It is possible therefore that the predominance of quartz in the earlier gravels may indicate an earlier period in which the slopes had less declivity and disintegration exceeded transportation.[3] The fact that in the Light's cañon region of Plumas county the gravel is underlain by a sheet of residuary material which was formed before the deposition of the gravel is evidence in the same direction. Furthermore, the sand deposited with the gravel is rough, angular and unassorted, such as is derived from residuary material near at hand, and records a period of gentler declivity during the next earlier epoch.

The old channels of auriferous gravel of the first period are in a measure characterized by the large size of the deposits. Ross E. Browne states:[4] "In a general way it may be said that the channels of the second period differ from those of the first as follows: their beds are narrower, rims steeper, and accumulations of bed rock gravel incomparably smaller." In these large accumulations of older gravels Prof. Whitney saw evidence of larger streams and heavier precipitation during the gravel period than now belongs to that region,[1] but, as pointed out by Mr. Gilbert,[2] deposition in stream channels is indicative of diminished instead of increased rainfall.

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[1] Tenth Annual Report, State Mineralogist of California, 1890, pp. 437-439.

[2] See also J. D. WHITNEY'S Auriferous Gravels of the Sierra Nevada, page 323, who says "that in some localities the gravel is almost entirely made up of quartz boulders and pebbles."

[3] Mr. BAILEY WILLIS some time ago, in his study of the Appalachian region, came to a similar conclusion, yet unpublished, to account for the predominance of quartz pebbles in the conglomerate at the base of the Coal Measures.

[4] Tenth Annual Report State Mineralogist of California, pp. 439–441.

Professor Le Conte regarded the gravels as "deposits made by the turbulent action of very swift, shifting, overloaded currents" supplied with both water and debris "by the rapid melting of extensive fields of ice and snow" which were then supposed to occupy the higher portion of the range.[3]

A very important contribution to the literature of the auriferous gravels has been made lately by Mr. W. Lindgren, whose views are expressed in the following quotation:[4]

> "From the rugged country in the region of their sources the rivers pursued their course down in broad valleys separated by ridges which even in the lowest foot-hills sometimes reached an elevation of a thousand feet above the channels. The outlines of the ridges were usually comparatively gentle and flowing; still, slopes of ten degrees from the channel to the summit were common and slopes as high as fifteen degrees occurred in the eastern part of the Sierra. The character of a region of old and continued erosion, commencing probably far back in the Cretaceous period, is everywhere plainly evident. In the center of the deep depressions is quite frequently found a deeper cut or "gutter," indicating a short period of more active erosive power just before the beginning of the gravel period. At this time, probably about the beginning of the Miocene period, the streams became charged with more detritus than they could carry and began to deposit their load along their lower courses, especially at places favorably situated, as, for instance, along the longitudinal valley of the South Yuba. Toward the close of the Neocene, gravels had accumulated all along the rivers up to a (present) elevation of about 5,000 or 6,000 feet; above this it is plain that erosion still continued in places with great activity and furnished some of the material deposited in the lower parts of the streams. The coarse character of much of the gravel and

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[1] Climatic Changes in later Geological Times, p. 1. See also Auriferous Gravels, p. 335.

[2] Science, Vol. I., p. 194, March 23, 1883.

[3] Am. Jour. Sci., Vol. XIX., 1880, p. 184.

[4] Bul. Geol. Soc. of Am., Vol. 4, pp. 265–6.

the often remarkable absence of fine sediments in the beds point clearly to a somewhat rapid stream capable of carrying off a great deal of silt, and the accumulations are probably due to rapid overloading rather than to low grades of the rivers. The deep channels were filled and the gravels encroached on the adjoining slopes, where they were deposited in broad benches. A maximum thickness of 500 feet of deposits was attained on the South Yuba, and of from 50 to 200 feet in the other parts of the lower rivers. In the lower and middle Sierra some of the rivers then meandered over flood-plains two or three miles wide, above which the divides of bed-rock rise to a height of several hundred feet. In some instances low passes over divides were covered, and temporary bifurcation and diversion of rivers into adjoining watersheds occurred."

It is evident from the facts already known that at the time the early gravels were deposited the northern end of the Sierra Nevada was not less than 4,000 feet lower than at the present time, and that its climatic circumstances as indicated by its flora were not such as to give rise to either glaciers or extensive fields of snow.[1] For this reason it is necessary to appeal to some other cause than glaciers as the source of the great mass of debris deposited in the old auriferous gravel channels, and in view of the facts herein cited, the writer suggests that a source may be found in the large mass of residuary material upon the surface at the beginning of the gravel period. There is evidence, as already shown, that at the close of the Tejon disintegration exceeded transportation, and residuary deposits accumulated upon the gentle slopes of the land to considerable depths. This condition appears to have continued during the early Miocene. The depth of disintegrated rock would vary greatly with different formations. Upon the diorite and other rocks containing minerals subject to ready alteration it would be deepest, and their surfaces, at least in the case of the diorite, would be strewn as to-day with large and small boulders of disintegration. The quartz veins which intersect these rocks and the silicious slates would be but little affected. The gold not enclosed in quartz veins[2] would be set free.

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[1] See also WHITNEY'S Auriferous Gravels, p. 295.

[2] WHITNEY'S Auriferous Gravels, p. 352.

If, when thus mantled with residuary material, the Sierra Nevada region were affected by a change of level in such a way as to slightly increase the fall of the streams upon its slopes, it is believed, as already suggested, that during a comparatively brief period owing to overloading they would be forced to deposit and fill their channels. A portion of the process is, in a measure, illustrated by what has taken place along some of the present streams of the Sierra Nevada where hydraulic mining has been extensively carried on. The streams are overloaded by the debris forced into them from the mines and their channels are at least temporarily filled with gravel.

After the deposition of the earlier gravels the declivity of some of the streams at certain points appears to have been so decreased that they deposited finer material and covered the gravel with sand and clay. This may have resulted from differential elevation, differential subsidence, or both, and there is evidence that both occurred within the gravel period. At Cherokee Flat upon the eastern border of the Sacramento valley the finer, essentially estuarine deposits, over 300 feet in thickness, lap over to the eastward upon the ancient river and shore gravels mined at that place. This overlapping evidently resulted from a subsidence of that region.

SUMMARY.

A study of the ancient topographic features upon the borders of the Sacramento valley, in the Klamath Mountains, and upon the western slope of the Sierra Nevada, shows that during the earlier portion of the auriferous gravel period, southern California, by long continued degradation, was finally reduced approximately to baselevel conditions. The mountain ranges were low, and the scenery was everywhere characterized by gently flowing slopes.

The distribution of the Ione formation and the early auriferous gravels, as well as the plant remains which they contain, point clearly to the same conclusion.

The topographic revolution consisted in developing out of such conditions the conspicuous mountain ranges of to-day.

The northern end of the Sierra Nevada has since been raised at least 4,000 feet, and possibly as much as 7,000 feet, and a fault of over 3,000 feet developed along the eastern face of that portion of the range. The Klamath Mountains may in some portions have experienced at the same time an equal upheaval. From all sides the amount of uplift decreased rapidly toward the Sacramento valley.

In the initial part of this revolution the earlier quartzose auriferous gravels were formed. The source of their material was found in the thick deposits of residuary detritus which had accumulated upon the surface of the land during the baselevel period. This large accumulation of disintegrated rock substance rendered the loading of the streams so easy that when rejuvenated by orogenic movements they became overloaded and filled their ancient channels with auriferous gravels.[1]

J. S. DILLER.

U. S. GEOLOGICAL SURVEY, Washington, D. C.
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[1] Since this paper was written a very important one has been published by Prof. A. C. LAWSON, on the Post-Pliocene Diastrophism of the Coast of Southern Calfornia. University of California, Bulletin of the Department of Geology, Vol. I., No. 4, pp. 115-160.